International Journal of Health Sciences and Research
www.ijhsr.org ISSN: 2249-9571

Review Article

Mushroom Polysaccharides as a Potential Prebiotics

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Received: 10/05//2013 *Revised: 18/06/2013* *Accepted: 04/07/2013*

ABSTRACT

Prebiotics are considering as non-digestible food ingredients which stimulate the growth of beneficial bacteria in the gastrointestinal tract. It mainly consists of the dietary fibers and oligosaccharides. They are having the beneficial effects like gut health maintenance, cancer inhibition, immunopotentiation, cholesterol removal, prevention of obesity. One of the potential sources of the prebiotics is mushroom polysaccharides. Mushroom fruiting body contains high amount of polysaccharides i.e. lentinan, β-1,3 glucan, β-1,6 glucan, grifolan and its showed multiple health benefits i.e. immunosuppressive, anticancer, hypertension, diabetes, stimulate the probiotics. Hence these fruiting bodies extracts extends their use for the human health.

Keywords: Prebiotics, Mushroom, Polysaccharides, Probiotics.

INTRODUCTION

Prebiotics are defined as non-digestible oligosaccharides and polysaccharides that promote the growth of the beneficial bacteria in the gastrointestinal tract and exert the antagonist effect on opportunistic and pathogenic bacteria. [1] The term prebiotics was coined by Gibson and Roberfroid. Gibson and his coworkers in 1995 given the concept of prebiotics by mentioning the following criteria viz. resistance to gastric acidity, gastrointestinal absorption, and selective stimulation of growth of beneficial bacteria reside in the gastrointestinal tract. Various prebiotics gained importance in market such as inulin, fructo-oligosaccharides, galacto-oligosaccharides, lactulose, polydextrose. [2]The other emerging prebiotics are isomalto oligosaccharides, xylo oligosaccharides and lactitol.

Due to westernization in our diet and high consumption of carbohydrate rich diet and soft drink etc. leads to various metabolic diseases such as overweight, obesity, diabetes, coronary disease, cancer. [3,4] Due to the poor nutrition, tobacco and alcohol consumption, there is increase in the morbidity and mortality. Hence there has been increase in the demand of the prebiotics.

Benefits of the prebiotics [5,6]

1. It promotes the growth of beneficial bacteria and discourages the overgrowth of pathogenic bacteria.
2. Slows absorption of glucose and reduce insulin resistance improving blood sugar.
3. Improves lipid profile, lowering LDL cholesterol and triglycerides while raising HDL cholesterol which may reduce the risk of coronary heart disease.
4. Prevents inflammation of the intestinal lining and leaky gut syndrome. It prevents or improves chronic inflammation.
5. Helps to regulate the immune system preventing infections and autoimmune disorders like allergies, asthma and eczema and serious autoimmune diseases.
6. Stimulates intestinal fermentation of soluble fiber into short chain fatty acids like propionate and butyrate, which may be beneficial and provide nutrients to mucosal lining of gastrointestinal tract.
7. Prebiotics are beneficial to Crohn's disease through production of short chain fatty acids to nourish the colon walls, and beneficial to ulcerative colitis through reduction of hydrogen sulfide gas due to reduction of sulfate-producing bacteria.
8. Potential effects on calcium and other mineral absorption, bowel pH, reduction of colorectal cancer risk, inflammatory bowel disorder and intestinal irregularity.

Mechanism of prebiotic

The impact of prebiotics on the organism is indirect, because prebiotics is not digested by host metabolic enzymes but the microbes present in the gastrointestinal tracts digest the substrate and in turn helps to improve the beneficial microorganism's counts. [3]It is thought, that molecular structure of prebiotics is important taking into consideration the physiological effects, and that it determines which microorganisms are actually able to use that prebiotics. [7] The most important function of prebiotic action is its influence on the microorganism's growth and number in the large bowel. The tests have been conducted in order to investigate the potential pathogenic and anticancer action of prebiotics, their ability to decrease the presence of large bowel diseases. [8] A lot of different potential beneficial influences on human organisms are being sought, and those are, among the others: increase of the volume and improvement of stool moisture, lowering of the cholesterol level, decrease of the amount long chain fatty acids in bowels, decrease of pH in bowels, increase of mineral compounds absorption and raised short chain fatty acids production. [9]

Mushroom: Mushroom term is not botanically accepted but it is generally known as 'Fruiting body of macro fungus.' [10] Fruiting body means the spore producing organ formed by mycelium and has stripes which have a cap on the top. There are many varieties of gilled fungi, with or without stem.

Structure of mushroom: Mushroom is a fruiting body consisting of cap, gills and stem. These structures are described in detail as follows. The structure of mushroom is shown in the figure 1.

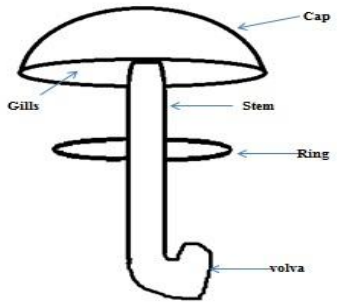


Fig1. Structure of mushroom.

The cap: It can be shaped differently depending on the species and the stage of growth. It can be conical, flat or even spherical. [11] The surface can be smooth, hairy or carry scab like fragments which are usually remnants of a universal veil if one was present.

The Gills: Usually present on the lower surface of the cap and composed of many thin layers stacked side by side. [12] Some mushrooms will have pores instead of gills. These are tiny tubes packed closely together forming a sponge layer. The lower side of the cap maybe smooth wrinkled or veined. Whichever form it takes, this is where the spores are produced. Finer distinctions are often made to distinguish the types of attached gills: adnate gills, which adjoin squarely to the stalk; notched gills, which are notched where they join the top of the stalk; adnexed gills, which curve upward to meet the stalk, and so on. These distinctions between attached gills are sometimes difficult to interpret, since gill attachment may change as the mushroom matures, or with different environmental conditions.

The stem: Stem or shaft of the mushrooms helps in nutrients absorption. Some mushrooms do not have a stem. Some has a ring or skirt below the cap; as it remains of the protective cover for the gills called a veil, which protects the gills when young. [13] As the cap expands or grows, the veil ruptures leaving the skirt like ring on the stem. This can be very obvious in some species and barely visible in others. There is another type of veil occurring in some species called a universal veil. This covers the whole mushroom as it emerges from the ground, and as it grows, the veil breaks leaving behind the volva or cup. Remnants of this type of veil can also been seem on the upper surface of the cap in some species.

A mushroom develops from a nodule or pinhead, less than two millimeters in diameter, called a primordium, which is typically found on or near the surface of the substrate. It is formed within the mycelium, the mass of thread like hyphae that make up the fungus. The primordium enlarges into a roundish structure of interwoven hyphae roughly resembling an egg, called a "button". The button has a cottony roll of mycelium, the universal veil that surrounds the developing fruit body. As the egg expands, the universal veil ruptures and may remain as a cup, or volva, at the base of the stalk, or as warts or volval patches on the cap. Many mushrooms lack a universal veil, therefore they do not have either a volva or volval patches. Often, a second layer of tissue, the partial veil, covers the bladelike gills that bear spores. Mushrooms lacking partial veils do not form an annulus.

Mushroom polysaccharides

Mushrooms are the rich dietary source which contains carbohydrates and several health promoting effects. [14] Mushrooms are also rich in the non-digestive dietary fibres which are glucan, chitin and hetropolysaccharides. It may also prevent viral infection by enchaning the growth of probiotic bacteria in the large intestine. Mushroom polysaccharides are potential source of prebiotics as it contains nutrients such as chitin, hemicelluloses, α & β-glucan, mannans, xylans and galactose. Several thousand species of mushroom were considered edible approximately 2000, out of which 20 are cultivated commercially but only 4-5 are industrially produced. It was also found that there is significant difference in the nutritional value of the stalk and pileus.

The mushroom contains high amount of carbohydrates in comparison to the proteins and fats. [15] Various minerals and vitamins are also present in the mushroom. Different mushroom produces the different

types of polysaccharides which could be either water soluble or insoluble. Some polysaccharides have only glucose moiety and some have proteins attached with it. Polysaccharides are almost β-linked glucose molecules but some also have galactose and mannose, some are heteropolysaccharides and others are glucan-protein complexes. The species which could be widely used for the prebiotics purpose are viz. Agaricus bisporus, Agaricus bitorquis, Agaricus blazei, Auricularia auricular-judae, Boletus erythropus, Calocybe indica, Flammulin avelutipes, Ganoderma Lucidium, Geastrums accatum, Hericium erianaceus, Lentinus edodes, Phellinus linteus, Pleurotus eryngii, Pleurotus florida, Pleurotus ostreatus. [16]

Types of mushroom polysaccharides and its importance

Mushrooms are used as medicine since the Neolithic and paleolithic period. [20] First time in 1960, scientists knew the active chemicals are present and they found that these active chemicals were polysaccharides. These polysaccharides could be used in treatment of as simple to complex diseases like cancer, AIDS and other present day diseases. The different types of polysaccharides and their benefits as prebiotic are described below.

D-Glucan

D-glucans are polysaccharides of the D-glucose molecule which may be linked by α or β glycosidic linkage. [21] The most important activity carried out by these polysaccharides is the ability to modulate the immune system. Glucans are known to activate *Lactobacillus rahmosus, Bifidobacterium bifidium* and *Enterococcus.* [22] Two types of the β-glucan molecules are found that are β-1,3glucan and β-1, 6 glucan.

β-1, 3 glucan

β-1,3 glucan are the polysaccharides of glucose molecule that are linked by β-1,3 linkage. [23] This β-glucan molecule binds effectively with the innate immune compartments like NK cells and macrophages. [21] It was reported that 0.1-0.5% in the diet stimulate the IL-4, IL-12 and IFN productions. It is also used for the antiallergic purpose. It was proved by experimenting on mice that were infected with the cedan pollen which create symptoms in human like sneezing, nasal congestion and conjunctivitis. Glucans molecules are found to modulate the innate system, there are number of receptors for the glucan to bind with them. The receptors are dectin-1, complement receptor-3, TLR2 and TLR6. Dectin is widely expressed on the dendritic cells, macrophages, neutrophils, monocytes and T-cells. It was found that there is synergestic effect when there is interaction between dectin-1 and TLR2 when they bind with β-glucan.

B-1, 6 glucan

β-1, 6 glucan are the polysaccharides of glucose molecule with β-1,6 linkage. [23] These glucans molecules are attached with the protein or other sugars moiety are widely used in the antitumor activity. These molecules are heteroglucan, arabinoglucans and acidic glucans. The glucans isolated from the *Ganoderma* species are only used for antitumor activity. β-glucans are also known to reduce the cholesterol level and LDL levels in the hypercholesterolmeic patients. Hence it downregulate the genes involved in lipogenesis and lipid transport. The *Pleutous* species glucans are also used for the antitumor activity but they are not much efficient. They are more potent analgesic and anti-inflammatory.

Lentinan

Lentinan is polysaacharides like glucan which are arranged in triple helix structure. It is triple helix polysaccharides and activates the *Escherichia coli* and

inhibits *Salmonella.* [22] It was found that it has an antitumor activity. [10] Abel *et al* in 1989 found that lentinan increased the production of macrophages and hence there was increase in the phagocytosis. [24] It was also found that when horse radish peroxidase is added with the lentinan it increases the inhibitory effect much more due to the stimulation of the pinocytosis.

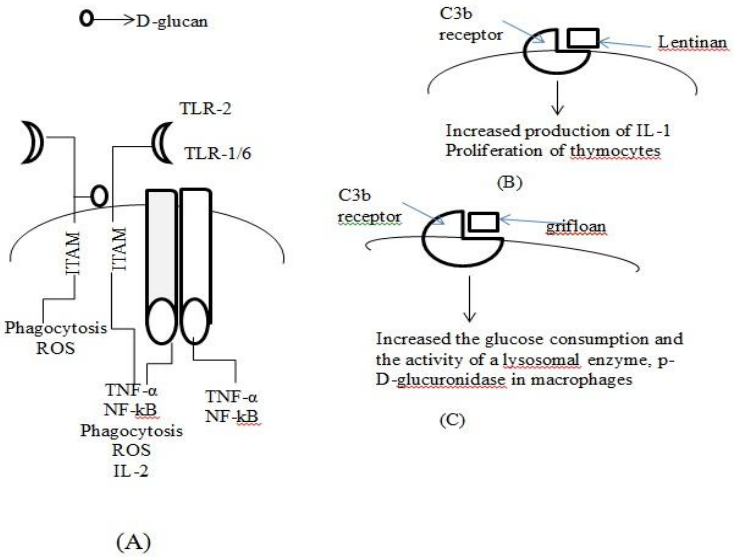
Grifloan

Grifloan are the β-linked glucose molecule having triple helix structure and activate the *Bifidobacterium* and *Lactobacillus* and show inhibitory effect on *Salmonella.* Grifloan has the same activity like lentinan. [10] It increased the glucose comsumption and activity of lysosomalenzyme, β-D glucourinodase in macrophages. It also effectively stimulates the production of interleukin, tumor nacrosis factor. The other effects found were increase in actue phase proteins, vascular dilation and hemorrhage. These were the beneficial effects of the mushroom polysaccharides.

Conceptual model for the interaction between mushroom polysaccharides and innate immune receptors as expressed on macrophages.

β-glucans

β-glucans exert immunomodulatory effects via activation of innate pathway in macrophages. β-glucans stimulate the productionof TNF-α, IFN-γ and IL-12(Fig 2a). β-glucans bind with the dectin-1 receptor on the cellwall of macrophages and allow the activation of TNF-α,IFN-γ, phagocytosis and NFk-B. [20]



Lentinan

Lentinan activate the production of interleukin-1 and also stimulate the proliferation of thymocytes when it combines with c3b receptor on the cell wall of macrophages (Fig 2b). [9]

Grifloan

Grifloan exert beneficial effect when it combined with the c3b receptor (fig 2c). It increased the glucose consumption, activity of the lysosomal enzyme and p-D-glucuronidase in macrophages. It is also

stimulating the production of IL-1, TNF-α and IL-6. [9]

Features of polysaccharides occurring in the mushroom

There are common belief that bioactive molecules are present in the plant materials, yeasts and bacteria, but today it is found that the mushroom also have the bioactive chemicals which have medical importance. Stalk is known to contain high amount of polysaccharides. Different species of mushroom are known to produce different polysaccharides which have different activities. The list of several polysaccharides present in the mushroom is described in the table 1.

Table:1. List of polysaccharides present in the mushroom.

Mushroom	Types of polysaccharides	Structural features	Importance	References
Agaricus bisporus	Heteropolysaccharides	Mucilage composed of glucose andGalactose	Activation of macrophages	[17]
Agaricus bitorquis	Homopolysaccharides	β-(1→3)-linked glucan	Activation of natural killer cells	[16]
Agaricus blazei	Glucan-protein complex	α, β-glucan	Activation of T-lymphocytes	[16]
Auricularia auricula-judae	Homopolysaccharides	β-(1→3)-D-glucan with branches at (1→6)	Antiviral activity	[17]
Boletus erythropus	Homopolysaccharides	(1→3)-linked glucose with branches at *O*-6	Antimicrobial activity	[16]
Calocybe indica	Homopolysaccharides	αβ-(1→4),(1→6)-glucan	Downregulate lipogenesis genes	[16]
Ganoderma lucidum	Heteropolysaccharides	β-(1→3)-linked D-glucan	Induction of apoptosis	[16]
Geastrum saccatum	Glucan-protein complex	β-linked glucan	Treatment in stomach cancer	[18]
Grifola frondosa	Heteroploysaccharides	Grifloan	Antitumor activity	[10]
Lentinus edodes	Heteropolysaccharides	Lentinan	Antitumor activity	[10]
Phellinus linteus	Homopolysaccharides	β-(1→3)-linked D-glucan	Increase production of interleukin	[16]
Pleurotus eryngii	Homopolysaccharides	α-(1→3)-linked D-glucan	Antiproliferative effect	[18]
Pleurotus florida	Homopolysaccharides	α-(1→3)-D-glucan branched at *O*-3 and *O*-6 by β-D-glucose, β-(1→3),(1→6)-D-glucan	Inhibit tumoral cell to cell adhesion	[16]
Pleurotus ostreatus	Homopolysaccharides	(1→3),(1→6)-D-polysaccharide, (1→3),(1→6)-D-polysaccharide	Increase gastrointestinal motility	[16]
Schizophyllum commune	Homopolysaccharides	Schizophyllan	Antitumor activity	[10]
Sparassis crispa	Homopolysaccharides	β-(1→3)-D-glucan	Lipid peroxidation inhibition	[16]
Termitomyces eurhizus	Homopolysaccharides	β-(1→3)-D-glucan	Anti-aging effects	[18]
Termitomyces microcapus	Homopolysaccharides	β-D-glucan	Hepatoprotectiveactivity	[19]

CONCLUSION

Mushroom polysaccharides not only activates probiotic that sustain in the gastrointestinal tract but also showed medicinal effects like tumor therapy, cardiovascular disease, anti-viral, anti-bacterial, antioxidant activates anti-aging activity and reduces the obesity. Hence mushroom can be considered as a potential prebiotic in future.

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How to cite this article: Bhakta M, Kumar P. Mushroom polysaccharides as a potential prebiotics. Int J Health Sci Res. 2013;3(8):77-84.

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